The Valve Wizard

How to design valve guitar amplifiers!

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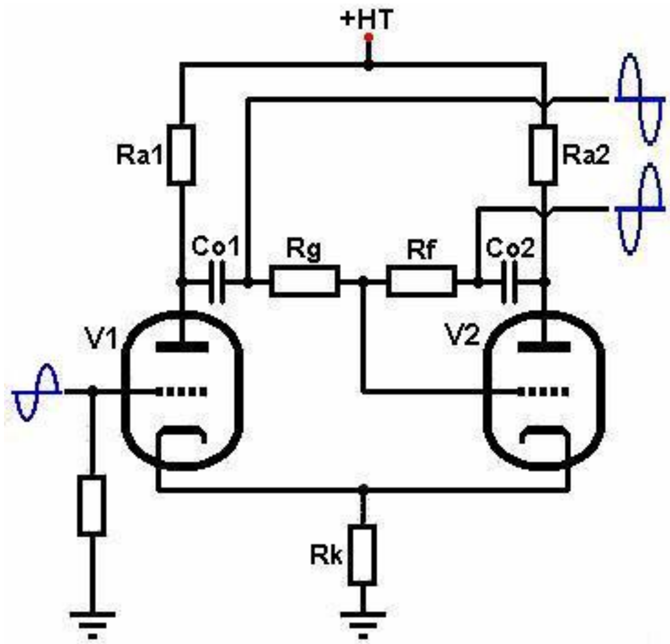
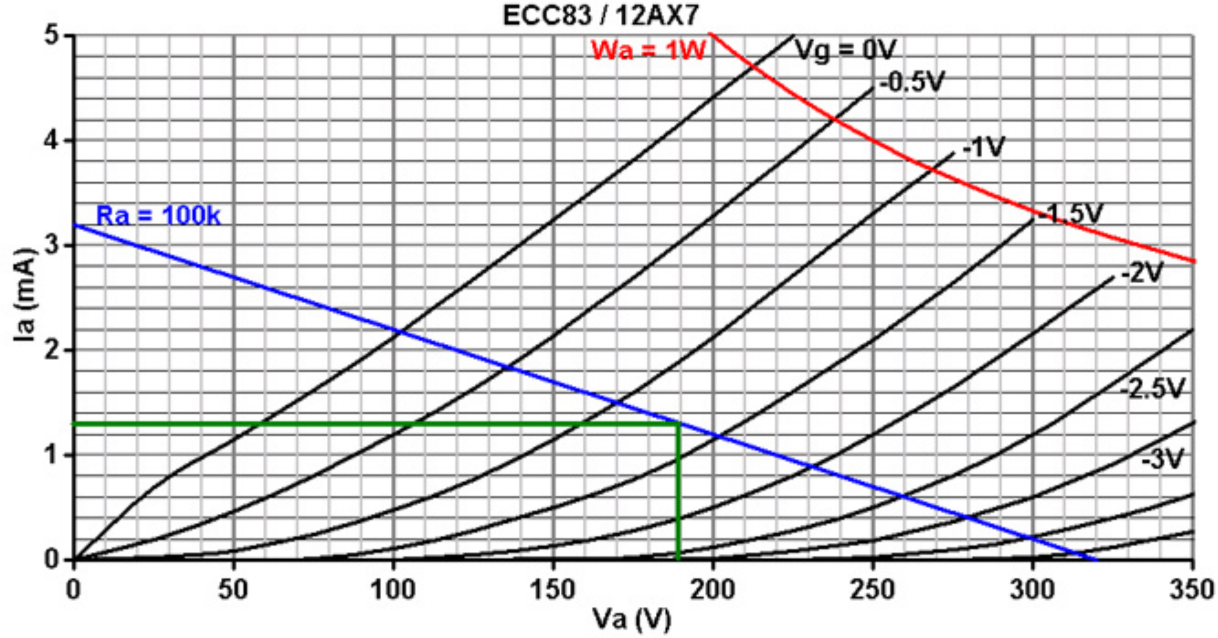
The Floating Paraphase Inverter

The floating paraphase or 'see-saw' phase inverter is very rarely seen in guitar amplifiers, although Ampegs are an exception. It can be thought of as a cross between the long tailed pair and the paraphase



The cathodes do not have to be connected together, although traditionally they are, as this saved on the cost of an extra bias resistor. It has been suggested that leaving a shared bias resistor unbypassed will improve the balance of this circuit, however, it actually introduces a little positive feedback. Therefore, this old-fashioned arrangement should not be used for hifi, but is ok for guitar. The first triode feeds one power valve and also the paraphase triode, which is arranged to have unity gain,so that it simply inverts the input signal.
Rg and Rf are usually made equal in value, as this approximately gives a gain of unity. This circuit has the advantage over the long tailed pair in that it has greater output signal swing, higher gain and puts little strain on the heater-cathode insulation.
Both triodes are usually the same and any type is suitable.

The design of the first triode is exactly the same as for a normal gain stage. A suitable load is selected, a load line is drawn and bias point chosen (usually the one that provides the most headroom, as in the long tailed pair). The same value anode resistor is used for the second triode (assuming both triodes are of the same type) so the same load line can be used for both. The following example uses an ECC83 (12AX7), with anode loads of 100k and an HT of 320V:



In this case a bias of -1.25V looks good, giving a quiescent anode current of 1.3mA. Because the cathodes are connected together so both triodes share the same bias point, twice the current must flow through the bias resistor, making 2.5mA. Use Ohm's law to find the bias resistor (Rk):
1.25 / 0.0026 = 481 ohms.
The nearest standard is 470R, although 680R would also be a good choice. It could be bypassed, if desired.
Normal rules apply for the grid-leak of the first triode, and 1Meg is usual.

Applying feedback: The grid resistor (Rg) sets the input impedance of the second triode, and it is usual to make it at least ten times larger than the anode resistor, so as not to load down the first triode too heavily. A value of 1Meg is usual.
According to the feedback equation for an ideal amplifier:
Av = Rf / Rg
Since we would like unity gain (Av = -1), Rg must equal Rf, so we would use a value of 1Meg for both.
You might think that because a triode is *not* an ideal amplifier, the true gain will not be equal to unity using this method, and the Radio Designer's Handbook (4th ed.) provides the formula:
Rf = Rg * [(1 + 2) / (Ao - 1)]
And this could be used if more precise balance is required. See also the section on triodes with local feedback.)

Balancing the output impedances: The output impedance of the first anode is the same as for a normal gain stage:
Zout1 = Ra || ra
Zout1 = 100000 || 50000
=33.3k

The output impedance of the second anode will be much lower due to the local feedback applied, typically about 1k:
Zout2 = (Rg + Rf) * [ra / (Rg + Rf + ra - Rg * Ao)]
Zout2 = (1000000 + 1000000) * [50000 / (1000000 + 1000000 + 50000 - 1000000 * -65)]
= 1.5k
(Ao is the gain before feedback and was calculated from the load line, as was the value for ra.)

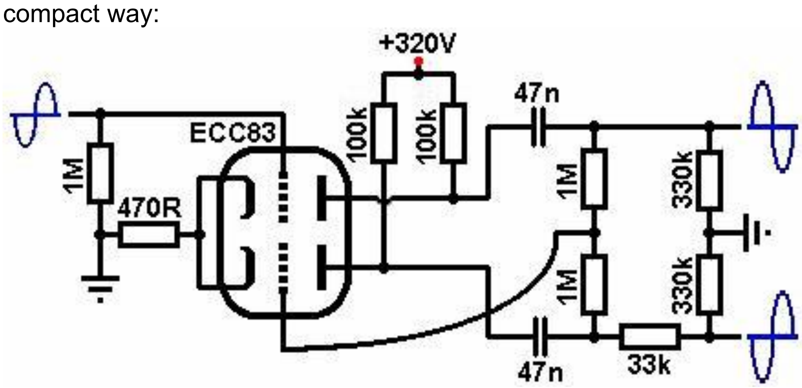
Therefore we might wish to add a build-out resistor to the second output, equal in value to the output impedance of the first triode, to give better balance. In this case the closest standard is 33k. (You don't actually need to carry out the previous calculation for Zout2, it was only for demonstration.) In the same way as mentioned in the section on the cathodyne, the build-out resistor could be replaced with a variable resistor to allow balance to be adjusted to taste.

Output coupling capacitors: Normally we would choose the output coupling capacitors based on the following load impedance. However, because Co2 is within the feedback loop it must have a low reactance at *all* audio frequencies or low-frequency resonance could occur. Its value should be chosen in conjunction with Rf. For a low-roll off of 1Hz:
C = 1 / (2 * pi * f * Rf)
C = 1/ (2 * pi * 1 * 1000000)

= 159nF
The nearest standard is 150nF. We would also get away with 100nF for a roll-off of 1.6Hz, or 47nF for a low roll-off of 3.4Hz. Co2 should be made the same in value or gross imbalance could occur.

Gain: The gain of the stage (to each anode) is equal to the gain of the first triode, which acts like a normal triode gain stage. This can be calculated from the load line, or from:
Av = (Ra * mu) / (Ra + ra)
(To be accurate, the value for Ra in the above equation should actually be the value of Ra in parallel with the following load, in this case the power valve grid-leak resistors (330k). This gives a true gain of about 60 in this case.)

The diagram [below] shows the finished circuit (for a cathode-biased power stage), drawn in a more compact way:



If the power stage is fixed biased then an additional coupling capacitor and grid-leak will be needed to block the DC reaching the grid of the second triode. The output coupling capacitors can be placed outside the local feedback loop and chosen in conjunction with the following input resistance; in this case the 470k grid-leak resistors of the power valves.